Early Palaeogene siliceous microfossils of the Middle Volga Region: stratigraphy and palaeogeography

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ABSTRACT
The Sengiley section (Middle Volga Region, Russia) provides one of the most complete late Palaeocene sedimentary sequence with well-preserved diatoms, silicoflagellates, and radiolarians. Three zones of regional zonal scheme (Kozlova 1994) based on radiolaria were distinguished in the sediments: *Buryella tetradica*, *Tripodiscinus sengilensis*, *Petalospyris foveolata* zones. Based on diatom regional scheme (Strelnikova 1992) *Trinacria ventriculosa* and *Hemiaulus peripterus* zones were recognised. Although assemblages of siliceous microfossils strongly differ from the oceanic coeval associations, the precise age of the boreal zones was determined on the basis of direct correlation with standard zonal scales of diatoms, silicoflagellates and radiolarians. For example, from sediments of *Petalospyris foveolata* zone, several species described by Nishimura (1992) from the upper part of the *Bekoma campechensis* standard radiolarian zone of the North-West Atlantic were found and allowed us to correlate these two zones. Two zones of the standard oceanic diatom scheme (Barron & Baldauf 1995) (*Hemiaulus peripterus* and *Hemiaulus incurvus* zones) and standard silicoflagellate *Naviculopsis constricta* zone were distinguished in the Sengiley section. Siliceous-terrigenous Palaeogene sediments of the Middle Volga can be considered as typical sediments of the marginal epicontinental basin. Siliceous assemblages of the Sengiley section are very close to assemblages from Lulinvort and Serov formations of the West Siberia and the eastern Urals slope, Fur Formation and Sambian Formation of North-East Europe, although the geometry of connections between these basins during late Palaeocene is still not clear.

KEY WORDS
Palaeogene,
biostratigraphy,
radiolaria,
silicoflagellates,
diatoms,
Middle Volga,
East European Platform.

RÉSUMÉ

Microfossiles siliceux paléogènes de la région de la moyenne Volga : stratigraphie et paléoécologie.

La coupe de Sengiley (région de la moyenne Volga, Russie) présente une des séquences sédimentaires les plus complètes du Paléocène supérieur avec des diatomées, radiolaires, silicoflagellés bien conservés. Trois zones de la zonation régionale (Kozlova 1994), fondée sur les radiolaires, sont distinguées dans les sédiments : zones à *Buryella tetradica*, *Tripodiscinus sengilensis*, *Petalospyris foveolata*. Dans la zonation régionale à diatomées (Strelnikova 1992), les zones à *Trinacria ventriculosa* and *Hemiaulus peripterus* sont reconnues. Bien que les assemblages à microfossiles siliceux diffèrent fortement des équivalents océaniques, l'âge précis des zones boréales a été déterminé sur la base de corrélations directes avec les échelles régionales standard à diatomées, silicoflagellés et radiolaires. Par exemple, pour les sédiments de la zone *Petalospyris foveolata*, plusieurs espèces décrites par Nishimura (1992) dans la partie supérieure de la zone standard à radiolaires à *Bekoma campechensis* du Nord Ouest de l'Atlantique ont été trouvées et nous permettent de corréler ces zones. Deux zones de la zonation océanique standard à diatomées (Barron & Baldauf 1995) (zones à *Hemiaulus peripterus* and *Hemiaulus incurvus*) et la zone standard à silicoflagellés à *Naviculopsis constricta* ont été trouvées dans la coupe de Sengiley. Les sédiments paléogènes siliceux-terrigènes de la moyenne Volga peuvent être considérés comme typiques de bassin marginaux épicontinentaux. Les assemblages siliceux de la coupe de Sengiley sont très proches des assemblages des formations de Lulinvort et Serov de Sibérie occidentale et du versant est de l'Oural, des formations de Fur et Sambian du Nord Est de l'Europe, bien que la géometrie des connexions entre ces bassins durant le Paléocène ne soit pas clairement établie.

MOTS CLÉS
Paléogène,
biostratigraphy,
radiolaires,
silicoflagellés,
diatomées,
Moyenne Volga,
Plate-forme est-européenne.

INTRODUCTION

In the Ulyanovsk-Saratov syncline of the Middle Volga Region (Fig. 1) widespread early Palaeogene sequence (approximately 300 m thick) is represented by marine siliceous-terrigenous deposits with high facies diversity. Previous stratigraphic subdivision of Palaeogene sequences was based in most cases on the lithological data. The age of these subdivisions and relations between them have been revised by different investigators more than once (Milanovsky 1940; Leonov 1961; etc.). The high abundance of siliceous facies, opokas (kryptogene siliceous deposits), the diatomites, siliceous clays and sands offer advantage for siliceous microfossils study.

FIG. 1. — Location of studied Sengiley section.

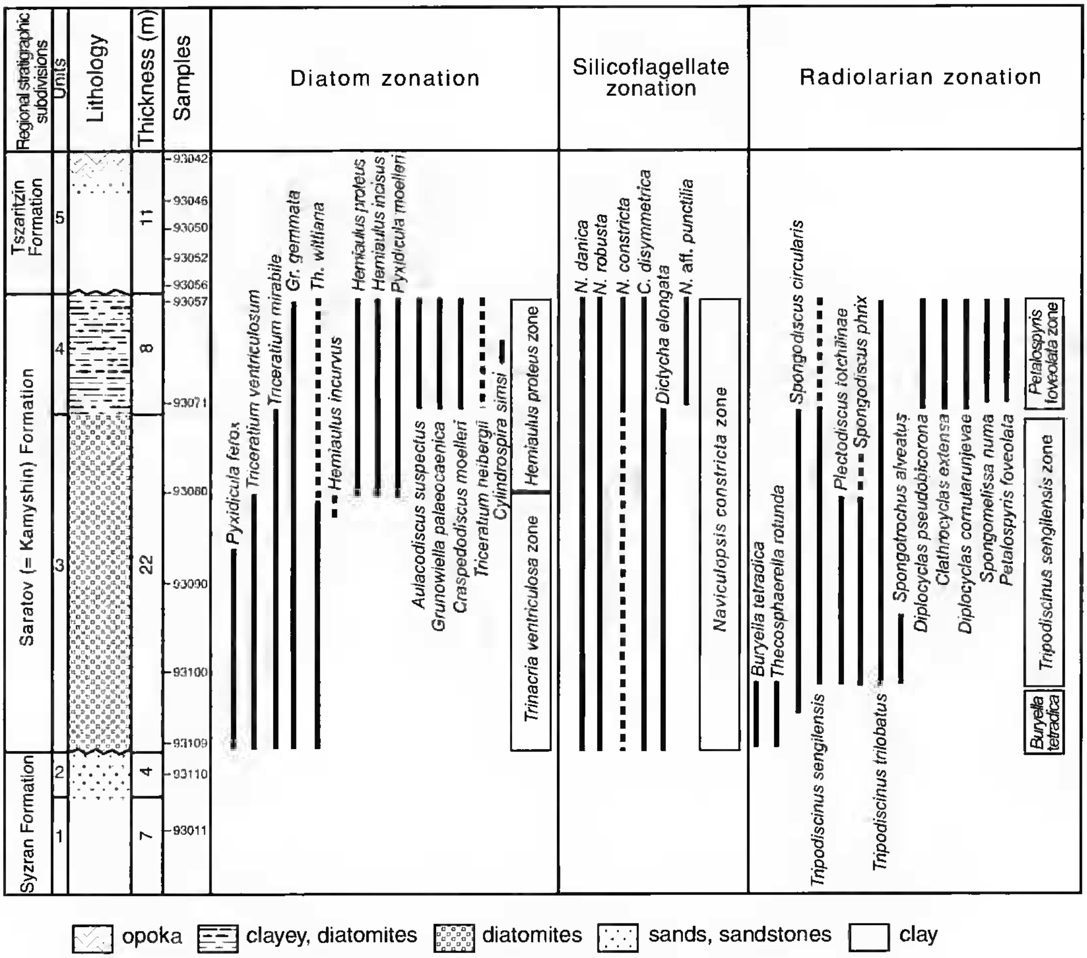

FIG. 2. — Lithology and lithostratigraphy of the Sengiley section, stratigraphic ranges of siliceous microfossils, and zonation. Schemes of Strelnikova (1992) (diatoms), Locker & Martini (1987) (silicoflagellates) and Kozlova (1994) (radiolarians) were used.

This paper seeks to examine the evidence provided by siliceous microfossils – diatoms, silicoflagellates and radiolarians which occur in the Sengiley section. Study of siliceous microorganisms from this section is very crucial for precise age determinations of Palaeogene sedimentary cycles and for revealing conditions of silica accumulation on the northern Peri-Tethyan margin. The problem of relations between these early Palaeogene biosilica accumulation events and regional and global geological events is also of great interest.

SENGILEY SECTION

The Sengiley section (Figs 1, 2) is located 7 km north-west of the Sengiley (Ulyanovsk Region). On the right bank of the Volga River, at an elevation of approximately 300 m above sea level, a section of 40 m high cliff so-called "Granoe Ukho" was studied. Up to the section the following lithological units were distinguished in the studied interval:

– at the river bank below the cliff siliceous grey clays of 7 m thickness; no microfossils found.

– siliceous dark-grey sandstones, thin-layered, with silica clays lenses, lie at the base of the diatomite cliff; thickness 4-4.5 m; no microfossil found.
– white massive diatomites with layers of light-grey diatomites, sometimes with glauconite; thickness 22 m; in samples 930109-930072 abundant siliceous microfossils were found.
– light-grey massive clayey diatomites lying conformably on the underlying unit; thickness 7 m; samples 930072-93057 contain abundant siliceous microfossils.
– the unconformity separates the diatomite units from overlying sediments; they are represented by sandy brownish-green clays, siliceous greenish-grey sands, brownish sandy opokas, silica dark-grey opokas; thickness about 11 m. Microfossils were not found.

PREVIOUS STUDY OF SILICEOUS MICROFOSSILS

Zonal subdivision of the Sengiley section on the basis of radiolarians has been proposed by Kozlova (1984). The age was considered as late Palaeocene. Radiolarian zones of this scheme are undoubtedly regional and can be traced in the boreal epicontinental Palaeogene of the Volga and Ural regions.
The study of diatoms of the Middle Volga Region was started in 19th century by Ehrenberg (1854), Grunow (1884) and Witt (1896). Later, diatoms and silicoflagellates from this location have been studied by Leonov (1961), Jousé (1979, 1982), Gleser (1993, 1995; Gleser *et al.* 1977) and Strelnikova (1990, 1992). The lower part of the diatomite unit is certainly related to the Palaeocene by all investigators, but an early Eocene age is still nor excluded for the upper part of diatomites. Silicoflagellate assemblages from several separated samples from the Sengiley section were studied and dated by Locker & Martini (1987) as early Eocene.

MATERIAL AND METHODS

Samples were collected during a field trip of Russian Academy of Sciences Geological Institute in 1994. 81 samples were examined for diatom and radiolarian biostratigraphy, but siliceous micro-organisms were found only in 55 samples from the diatomite units of the section. Sampling interval was approximately 50 cm.
Approximately 5 g of sample was crushed mechanically and placed into an 400 ml beaker. Then samples were processed by 15-minutes boiling in hydrogen peroxide. The procedure of repeatedly filling and decanting the beakers with distilled water and allowing 2 hr settling was used to remove chemicals and clay minerals.
Slides for radiolarian study were prepared on 24 × 24 mm cover glasses and mounted in Canadian balsam on 24 × 80 mm glass slides. Radiolarians were examined at × 400. Species were recorded as abundant (A) if more than 10 specimens were present in the slide, common (C) if 3-10 specimens occurred in the slide and rare (R) if 1-3 specimens were found.
Strewn slides for diatoms were prepared by sampling the suspended residue with a pipette spreading it on 18 × 18 mm cover slide and mounting in Elyashev mounting medium. Diatoms were examined at × 500. Species identification was checked at × 1250. Some samples were studied in SEM "Cambridge Stereoscan" microscope. Relative abundance of taxa represented in the range chart is reported as abundant (A) when 20 specimens are present in one horizontal traverse at × 500, common (C) when 3-19 specimens are present at each traverse, few (F) – 1-2 specimens in each traverse, rare (R) – less than one specimen in each traverse.

STRATIGRAPHY

Radiolaria

Using radiolaria, the section was subdivided on the basis of the boreal zonal scheme of Kozlova (1994). The zonal succession is Palaeocene (Fig. 1, Table 1).

Buryella tetradica zone

The assemblage is moderately preserved and contains *Buryella tetradica* Foreman, *Thecosphaera rotunda* Borissenko, *Spongotrochus puter*

TABLE 1. — Stratigraphic distribution of radiolaria in Sengiley section. **A**, abundant (20 specimens are present in one horizontal traverse examined at × 500); **C**, common (3-19 specimens are present at each traverse); **F**, few (1-2 specimens in each traverse); **R**, rare (less than 1 specimen in each traverse).

AGE	ZELANDIAN																	
ZONE	*Buryella tetradica*		*Tripodiscinus sengilensis*															
Species / sample number	**109**	**108**	**107**	**106**	**105**	**104**	**103**	**102**	**101**	**100**	**99**	**98**	**97**	**96**	**95**	**94**	**93**	**92**
Buryella tetradica	C	C	C	R														
Lophophaena curta			R	R	C	C	R	R										
Plectodiscus totchilinae				C	C	C	R	R										
Spongodiscus americanus			A	A	A	A	C											
Spongodiscus phrix			C	R	C	C	C	R										
Spongotrochus alveatus							C	C		R		R						
Spongotrochus sp. aff. *Trochodiscus cleve*							A	C										
Spongotrochus aff. *heliodes*										A	A	A	A	A	A	C	C	C
Spongotrochus paciferus					R		R			R		R						
Spongotrochus puler		C	C	C														
Thecosphaera rotunda		R	R	R														
Tripodiscinus sengilensis				C	C	C	C	C	R		R		R					
Tripodiscinus sibiricus		R	R	R			R	R	R	R	R	R	R					
Tripodiscinus trilobatus						R	R								R			

AGE	ZELANDIAN-THANETIAN																	
ZONE	*Tripodiscinus sigilensis*																	
species/sample number	**91**	**90**	**89**	**88**	**87**	**86**	**85**	**84**	**83**	**82**	**81**	**80**	**79**	**78**	**77**	**76**	**75**	**74**
Anthocyrtoma frizzeli					R		R											
Larnocalpis smili											C	R	R					
Lophophaena curta												R				R		
Phormocyrtis reticula											C	R						
Plectodiscus totchilinae					C	R											R	
Spongotrochus aff. *helioides*	C	R	C	C														
Spongomelissa ternaria					R	R						R						
Tropodiscinus trilobatus					C	C	C	R	C	R	R	R	R	R	R	R	C	
Tripodiscinus sengilensis		R			R													R

AGE	ZELANDIAN-THANETIAN					THANETIAN												
ZONE	*Tripodiscinus sigilensis*					*Petalospyris foveolata*												
species/sample number	**73**	**72**	**71**	**70**	**69**	**68**	**67**	**66**	**65**	**64**	**63**	**62**	**61**	**60**	**59**	**58**	**57**	
Acanthosphaera sp.										C	C	C						
Botryometra [illegible]												C	R	C		R		
Clathrocyclas extensa										R		R						
Clathrocyclas lipmanii										R	R							
Clathrocyclas longispina									A									
Diplocyclas cornuta runjevae						C	R		R	A	R	C	C					
Diplocyclas pseudobicorona pseudobicorone						R	C	C			R	C						
Periviator (?) *dumitricae*											R	R	R					
Petalospyris foveolata						R	R	C	C	C	C	R						
Spongasteriscus cruciferus						R	R			C	R							
Spongomelissa ternaria							C					R	R	R		R	C	
Spongomelissa numa numa						R	C					C						
Spongotrochus nativus praecox									A									
Stylodyctya hartestonensis							R		R	A		R	C	R				
Tripodiscinus trilobatus		R								R								

Kozlova, *Tripodiscinus sibiricus* Kozlova, *Spongodiscus americanus* Kozlova, *Spongodiscus phrix* Gorbovetz and *Lophophaena curta* Kozlova. The base of the zone was not observed in the section. The upper boundary is determined by the appearance of *Tripodiscinus sengilensis* Kozlova and *Plectodiscus totchilinae* Kozlova.

Tripodiscinus sengilensis zone

Radiolarians are abundant and well-preserved. The most common are: *Tripodiscinus sengilensis* Kozlova, *T. trilobatus* Kozlova, *Lophophaena curta* Kozlova, *Spongotrochus paciferus antiquus* Kozlova, *S.* aff. *Trochodiscus clevei* (Kozlova), *S.* aff. *helioides* Cleve, *Spongodiscus americanus* Kozlova & Gorbovetz and *Plectodiscus tochilinae* Kozlova. *Sponotrochus alveatus* Riedel & Sanfilippo, *Tripodiscinus sibiricus* Kozlova, *Stylodictya charlestonensis* (Clark & Campbell), *Anthocyrtoma frizzeli* Nishimura and *Periviator*(?) *dumitricae* Nishimura occur rarely. Common *Larnocalpis smili* Middour and *Phormocyrtis reticula* Kozlova & Gorbovetz were found in the upper part of the zone. The upper boundary of the zone is very sharp and determined by the appearance of *Petalospyris foveolata* Ehrenberg, *Diplocyclas cornuta runjevae* Kozlova, *D. pseudobicorana pseudobicorona* Nishimura, *Spongomelissa numa numa* Kozlova, *Clathrocyclas longispina* Clark & Campbell and *Spongotrochus nativus praecox* Kozlova.

Petalospyris foveolata zone

Radiolarians are diversified and well-preserved. The most abundant are: *Petalospyris foveolata* Ehrenberg, *Dyplocyclas cornuta runjevae* Kozlova, *D. pseudobicorona pseudobicorona* Nishimura, *Antocyrtoma frizzeli* Nishimura, *Botryometra osha* Kozlova, *Spongomelissa ternaria* Kozlova, *S. numa numa* Kozlova. In the lower part of the zone *Clathrocyclas longispina* Clark & Campbell, and *Spongotrochus nativus praecox* Kozlova are abundant. *Spongasteriscus cruciferus* Clark & Campbell, *Clatrocyclas extensa* Clark & Campbell and *C. lipmanii* Kozlova are rather rare.

Diatoms and silicoflagellates

Pronounced taxonomic changes in diatom assemblages observed in the middle part of Sengiley diatomites (Fig. 1, Table 2) allow us to distinguish from the base and upsection two zones of the zonal scheme for the Northern Hemisphere *sensu* Strelnikova (1990, 1992).

Trinacria ventriculosa zone is represented by common *Triceratium mirabile* Jousé, *Trinacria ventriculosa* (A. Schmidt) Gleser, *Pyxidicula ferox* (Greville) Strelnikova & Nikolaev, *Grunowiella gemmata* (Grunow) Van Heurck. The assemblage of the Hemiaulus proteus zone consists of *Hemiaulus incurvus* Shibkova, *H. proteus* Heiberg, *H. incisus* Hajos, *H. frigidus* (Grunow) Fenner, *Soleum ex-sculptum* Heiberg, *Triceratium heibergii* Gombos, *Craspedodiscus moelleri* A. Schmidt, *Aulacodiscus suspectus* A. Schmidt, *Grunowiella palaeocaenica* Jousé and *Cylindrospira simsi* Mitlehner.

Besides the stratigaphically important species enumerated above, diversified representatives of the neritic diatom flora of epicontinental basins are present in both zonal assemblages. A full list is shown in the Table 1 and in the taxonomic appendix.

Silicoflagellates (about 10 taxa) are common throughout the whole section. For stratigraphic subdivision, the zonation of Locker & Martini (1987) is applied. The appearance of members of the *Naviculopsis* genus (including *N. constricta* (Schulz) Frenguelli, *N. robusta* Deflandre, *N. danica* Perch-Nielsen) defines *Naviculopsis constricta* zone (upper Palaeocene-early Eocene). *Corbisema disymmetrica* Bukry is present throughout the whole section. According to Locker & Martini (1987), this stratigraphic interval corresponds to the NP4-NP9 nannoplankton zones and so gives us the possibility to restrict the age of the diatomite unit by the Palaeocene. Less pronounced than diatoms one, change in taxonomic composition is related to the middle part of the section. This reconstruction includes the last appearance of *Dictyocha elongata* Gleser and the first appearance of *Naviculopsis punctilia* Perch-Nielsen.

PALAEOECOLOGY

Radiolarian assemblages are well preserved and, for the epicontinental setting, diversified (33 spe-

TABLE 2. — Stratigraphic occurrence of diatoms and silicoflagellates in Sengiley section. Legend: see Table 1.

Diatoms/Samples	109	108	107	106	105	104	103	102	101	100	99	98	97	96	95	94	93	92	91	90	89	88	87	86	85	84
Aulacodiscus distinguendus										R									R						R	
Aulacodiscus probabilis										R									R			R				
Briggera sibirica	R					R		F		R	R	R	F	R	R		R	R	R	R	R					R
Costopyxis antiqua							R			R																
Eunotogramma variabile	R	R	R	R	R	R	R				R			R		R	R			R		R	R		R	
Eunotogramma weissii	F	F	F						R	C																
Grunowiella gemmata	C	A	C	C	A	A	C	C	C	C	F	C	F	F	F	C	C	F	F	C	C	A	C	C	A	A
Hemiaulus frigida	C	R	R	R	R	R	C	R	R	R	C	R	C	R	R	R	R	R	R	R	R	R	R	R		R
Hemiaulus ambiguus																									F	R
Hemiaulus danicus			R	F	F	R				R												R				
Hemiaulus incurvus																									R	
Hemiaulus rossicus																									F	F
Hyalodiscus radiatus	R	R	F	R	R	R	R	F	R	R	R	R	R			R	R		R	R						
Kentrodiscus fossilis																R	R								R	R
Lisitzinia distanovii																					R		R			
Odontotropis carinata	R				R	R	F	F	F	F	F	F	F	F	R	F	F	R	R	R	R	R	R	R	R	R
Odontotropis cristata								R	R	R	R				R		R		R	R						
Paralia crenulata		R		F			F				R	R	R		R	R	R	R	R	R						
Paralia grunowii								F	F	R	R	R	R		R	F	R	R	R	R	R	R	R	R	R	R
Paralia sulcata	R	F	R	F	R	R	F	F	F	F	F	F	F	F	F	F	F	F	F	F		R		F		
Proboscia cretacea	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	R	R	R	R	R	R
Pseudopodosira sp. 2																							F	R		
Pseudopodosira westii	R	F	R			R	R	R	R	R	R	R	R	R	R	R		R	R	R	F	F	F	F	F	F
Pseudostictodiscus angulatus	R	R	R	F	R	R	R	R	R	R				R		R	R	R	R	R	R		R	R	R	R
Pterotheca major	R						R			R												R			R	R
Pyxidicula ferox	C	C	C	C	C	C	C	C	C	C	F	F	F	F	F	F	F	F	F	F	F	F	F			
Rattrayella oamaruensis																			R	R			R			
Rhaphoneis morsiana																								R		
Rhaphoneis simbirskiana																									R	
Rhizosolenia hebetata			R																							
Stellarima microtrias	F	R	F	F	R	R	R	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F
Thalassiosira sp. 1							R																R			
Thalassiosiropsis wittiana	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	F	F	C	C	C	C
Triceratium tios										R																
Triceratium kinkeri	R	R	F	R	R	R	R	R	R	R	F	F	F	F	R	R	R	R	R	R	C	C	C	C	C	C
Triceratium mirabile	C	C	C	C	A	A	C	A	A	A	A	A	A	A	A	A	A	C	C	C	R	R	F	R	F	F
Triceratium ventriculosum	F	C	F	F	C	F	F	F	F	F	F	F	R	R	F	R	R	F	F	F	R	R	F	R	R	R
Trinacria pileolus	R	R	R	R	R	R	R	R	R	R	R	F	R	R	F	F	F	F	F	F	R					
Trochosira spinosa			R		R			R			R				R						R		R			
Silicoflagellates																										
Corbisema disymmetrica communis	R	F	R	F	F	F	R	F	F	F	F	F	F	F	F	F	F	R	R	R	R	R	R	R	R	R
Corbisema hastata hastata	F	F	F	R	R	F	F	F	F	F	C	C	C	C	C	C	C	C	C	C						
Corbisema hastata globulata																					R	R	R	R	F	R
Corbisema inermis inermis	R	R	R	R		R	R	R	R	R	F	F	R	R	R	R	R	R	R	R	F	F	F	R	R	F
Dictyocha elongata	C	F	F	F	F	F	F	F	F	F	C	C	C	C	C	C	C	C	C	C	F	F	R	F	R	R
Dictyocha fibula	R		R				R				R	R				R	R	R	R	R	R	R	R	R	R	R
Dictyocha precarentis										R	R	R	R	R			R	R		R		R			R	R
Naviculopsis constricta	R	R										R					R			R	R	R	R			
Naviculopsis danica													R			R				R						
Naviculopsis robusta	R	R			R			R		R	R	R		R		R	R		R	R	R			R		

Diatoms/ Samples	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63	62	61	60	59	58	57
Aulacodiscus distinguendus			R	R				R			R				R			R			R						
Aulacodiscus probabilis	R			R		R	R	R	R	R	R	F	F	F			R		R		R			R			R
Aulacodiscus schmidti		R			R				R	F							R		R							R	
Aulacodiscus suspectus												R	R	R	F	F	C	C	C	C	C	C	F	C	A	A	F
Briggera sibirica		F		R		R			R					R				R								R	
Craspedodiscus moellari												F	F	F	F	F	C	A	A	C	A	A	C	C	A	A	F
Cylindrospira simsi																	R	R	R	C							
Eunotogramma variabile		R	R	R																							
Eunotogramma weissii						R				R																	
Fenestrella antiqua												R						R									
Grunowiella gemmata	C	C	C	F	F	F	R	F	F	F	F	F	F	F	F	F	F	F	F	C	F	F	F	F	F	F	F
Grunowiella palaeocaenica												R	C	C	C	C	C	C	C	C	C	C	C	C	C	C	F
Hemiaulus ambiguus	R			R		R				R				R		R											
Hemiaulus arcticus var. *bornholmensis*			F			R			R		R		R		C	R	R	R	R	R	R	R	R	R	R	R	R
Hemiaulus curvatulus																	F	R	R	F	F	F	F	F	F	R	R
Hemiaulus danicus														R	R		R								R	R	R
Hemiaulus frigidus	R	R	R	R	R		R		R		R				R												
Hemiaulus incisus			R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Hemiaulus incurvus			R	R																							
Hemiaulus proteus				F	C	C	C	C	C	C	C	C	C	C	C	C	C	F	A	A	A	C	A	A	C	C	F
Hemiaulus rossicus		R		R													R	R									
Hyalodiscus radiatus	R		R			R		R	R	R	F	R	R	R		R	F	R	R	R	R	F	R	R	R	R	R
Kentrodiscus fossilis																		R			R						
Lisitzinia distanovii														R	R			R									
Odontotropis carinata	R	R	R	R					R	R	F	F	R	F	R	R	R	R	R	R	R	F	R	F	R	R	
Odontotropis cristata													R				R					R					
Paralia crenulata	R	F	F	C	C	C	F	F	R	R	F	R	R	R	R	R	R	F	R	R	F	R	R	R	R	R	R
Paralia grunowii	F	F	R	F	F	F	F	F	C	C	C	R	R	R			R	R				R	R	R	F	R	R
Paralia sulcata	F	C	C	A	A	A	A	A	F	F	F	F	A	A	A	A	A	F	F	F	F	F	A	A	A	C	R
Proboscia cretacea	R	R	R	R	R	F	R	R	F	F	R	F	F	F	R	R	R	R	R	F	R	R	R	R	R	R	R
Pseudopodosira sp. 2		F	F	R																			R	R			
Pseudopodosira westii	F	F	A	A	C	C	C	F	F	R	R	R	R	R	R	F	R	R	F	R	R	R	R	R	R	R	R
Pseudostictodiscus angulatus		R	R	R		R	R		R	R	F	R	R	R	R	R	F	F	R	R	F	R	R	R	R	R	
Pterotheca major			R				R							R			R							R			
Pyxidicula moelleri			R	F	F	F	F	F	F	F	C	C	C	C	C	F	C	F	F	F	C	C	C	C	C	F	R
Rattrayella oamaruensis											F							R			F						
Rattrayella rotundata					R				R		R								R		R			R			
Rhaphoneis morsiana	F				R							R				R						R			F	R	R
Rhaphoneis simbirskiana			F		F				F	R	F	F	F	F	R	F	F	F	F	R	F	C	C	C	F	F	R
Rhizosolenia hebetata					R					R		R					R										
Solium exsculptum		R	F	F	F	F	F	F	F	F	R	R	F	F	F	R	R	F	F	F	R	R	F	F	F	R	R
Stellarima microtrias	R	F	F	F					R	R	R	F	F	F	R	R	F	F	R	R	R	F	F	F	R	R	R

Diatoms/ Samples	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63	62	61	60	59	58	57
Thalassiosira sp. 1																								R			
Thalassiosiropsis wittiana	C	C	C							R				R			R						R				
Triceratium flos										R	R	R		R	F	F											
Triceratium heibergii												F	R	R	R	R	R	F	F	F	R		R		R	R	
Triceratium kinkeri	F	F	R	R																							
Triceratium mirabile	R	R	R	R	R	R	R	R	R	R	R	R	R						R	R	R				F	R	
Triceratium sparsipunctata					R										R	R	R			R		R					
Triceratium ventriculosum	R	R																									
Trinacria excavata		R	R	R	R	R	R	R	R	R	R	R	R	R	R	F	F	F	C	C	C	C	C	C	F	R	
Trinacria pileolus	R				R				R						C	C	C	C	C	C	C	C	C	C	C	C	R
Trinacria regina			R							R			R		R				R			R	R		R	R	
Trochosira spinosa	R								R			R							F	R				R	R		
Xanthiopyxis sp. 1												R	R	R													
Silicoflagellates																											
Corbisema disymmetrica communis	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Corbisema hastata hastata															R	R	F	R	R	F	F	F	F	F	R	R	R
Corbisema hastata globulata	F	F	F	R	R	R	R	R	R	F	F	F	F	F	R	R	R								R	R	
Corbisema inermis inermis			R			R			R		R			R													
Dictyocha elongata	R	R	R	R	R	R	R	R	R	R	R	R	R														
Dictyocha fibula	C	F	R				R				R			R													
Dictyocha precarentis	R		R				R				R				R	R			R	R				R	R		
Naviculopsis constricta					R					R	R		R	R	R	R	R	R			R				R	R	R
Naviculopsis danica	R		R		R		R		R	R		R		R			R					R		R			
Naviculopsis punctilia													R	R	R	R	R		R			R			R		
Naviculopsis robusta		R				R		R	R	R	R																

cies were determined). Different radiolarian species dominate the assemblage in specific stratigraphic intervals. For example, specimens of *Spongodiscus americanus* Kozlova & Gorbovetz dominate in the lowermost part of section (samples 109-104), *Tripodiscinus sengilensis* Kozlova in samples 106-101, *Spongotrochus* aff. *helioides* (Cleve) in samples 99-88, *Tripodiscinus trilobatus* Kozlova in samples 87-75, *Anthocyrtoma frizzeli* Noshimura and *Petalospyris foveolata* Ehrenberg in samples 65-60. Generally, in the lower part of diatomite unit, representatives of the Spongodiscidae family (genera *Spongodiscus* and *Spongotrochus*) and Trissocyclinae family (genus *Tripodiscinus*) are dominant, and in the upper part of diatomites specimens of the *Cyrtidae* (genera *Diplocyclas*, *Clathrocyclas* and *Anthocyrtoma*) and of the Spyridae (genus *Petalospyris*) dominate. The greatest change of the association can be observed at the stratigraphical level of samples 72-67 (Fig. 2), on the boundary between the *Tripodiscinus sengilensis* and *Petalospyris foveolata* radiolarian zones.

Diatom assemblages are well preserved and taxonomically diversified too, represented mainly by robust, large frustules of diatoms. About 60 taxa of diatom were determined. The diatom assemblages are dominated by species typical for neritic environment. Fully planktonically living species are represented by genera *Hemiaulus*, *Rhizosolenia*, *Proboscia*, *Thalassiosiropsis* and *Triceratium*.

In the upper part of the section (samples 80-71) a taxonomic turnover in diatom assemblages correlates with relative increase of the *Paralia sulcata* (Ehrenberg) Cleve group. It is possible that these changes testify the transition to the coastal, shallower environment. The same trend is reflected in the increasing of clayey material content in the upper part of the section and in the change of diatomites colour from white to grey.

DISCUSSION

STRATIGRAPHIC ISSUES

The precise age determination of siliceous

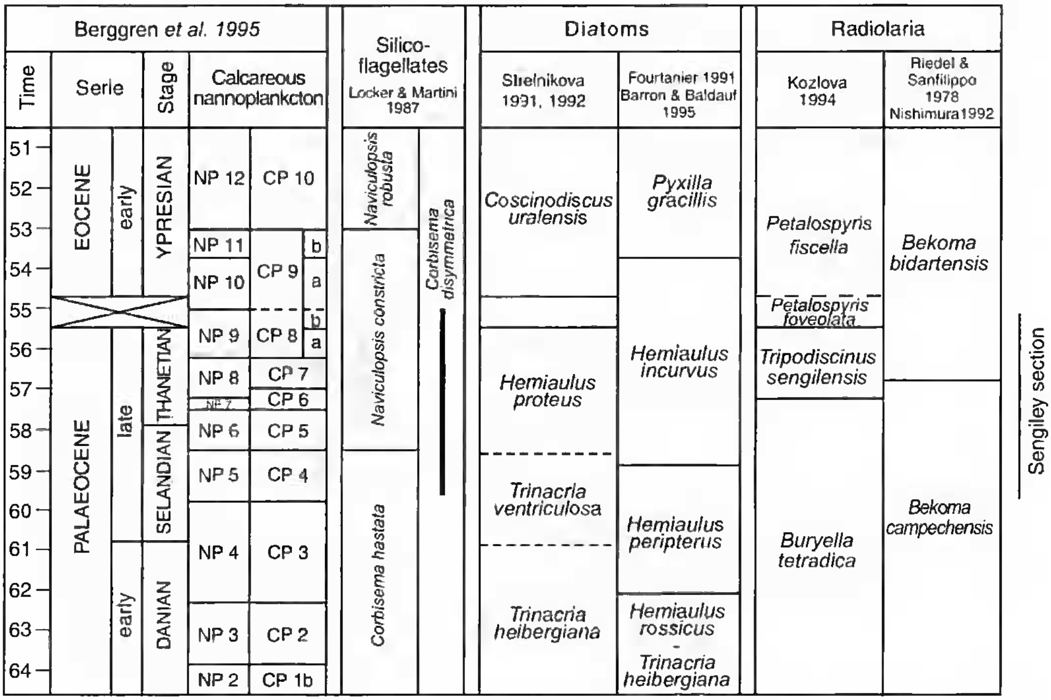

FIG. 3. — The stratigraphic position of the diatomites of the Sengiley section and correlation to standard and regional zonal schemes.

microfossils associations from the diatomite unit of the Sengiley section is very important to understand the stratigraphic position of the Middle Volga siliceous sediments (Fig. 3).

Present knowledge of stratigraphic ranges of Palaeocene diatoms and radiolarians is very limited, especially for the epicontinental basins. As a rule sediments do not contain any calcareous plankton and do not have not any palaeomagnetic data.

Besides in the Volga Region, the *Buryella tetradica* radiolarian zone can be distinguished in the North Precaspian Basin; the *Tripodiscinus sengilensis* zone can be observed in the Serov Formation of the eastern Ural slope and of the western Siberia; and the *Petalospyris foveolata* radiolarian zone can be recognised in the Irbit Formation of the eastern Ural slope (Kozlova 1984). These radiolarian zones are thus regional and can be traced across a wide territory.

Radiolarian zones distinguished in this paper were referred to the upper Palaeocene by Kozlova (1994) on the basis of a few species common to the associations from the Gulf of Mexico (Foreman 1973).

We suggest that the *Buryella tetradica* and *Tripodiscinus sengilensis* zones are related to the lower *Bekoma campechensis* zone of the standard radiolarian scale, in regard of the presence of *Buryella tetradica* Foreman, *Thecosphaera rotunda* Borissenko, *Spongodiscus americanus* Kozlova & Gorbovetz, *Spongotrochus alveatus* Riedel & Sanfilippo and *Periviator* (?) *dumitricai* Nishimura. Based on the presence of *Diplocyclas pseudobicorona pseudobicorona* Nishimura, *Spongasteriscus cruciferus* Clark & Campbell and *Anthocyrtoma* (?) *frizzelli* Nishimura, the *Petalospyris foveolata* zone seems to correspond to the upper part of *Bekoma campechensis* zone of the Northwest Atlantic and, correspondingly, to the CP5-CP6-lower CP7 nannoplankton zones (Nishimura 1992).

A similar picture is obtained from the diatom stratigraphy. The same succession of diatom assemblages (*Trinacria ventriculosa* and *Hemiaulus proteus* zones) is typical for the whole region, being reported from the boundary interval between the lower and middle parts of the Lulinvort Formation (Pur and Taz River basins) of western Siberia, the Irbit and Serov formations of the eastern Ural slope (Proshkina-Lavrenko 1974). Unfortunately, the precise age of these regional subdivisions remains unclear, for they can still not be correlated with the standard zonal schemes of calcareous microplankton. Strelnikova (1990, 1992) puts the foregoing zones into the late Palaeocene. Gleser (1994, 1995), the first who distinguished these zones, considered the lower zone as late Palaeocene and upper one as early Eocene. But, it is clear now, that for the subdivision of the Sengiley section, standard diatom zones, which were directly correlated with nannoplankton zones in sections from southern Indian Ocean (Fourtanier 1991; Barron & Baldauf 1995) can be used (Fig. 3). The taxonomic composition of the upper *Hemiaulus proteus* zone is like that of the *Hemiaulus incurvus* standard zone. The sharply different assemblage of the lower *Trinacria ventriculosa* zone allows us to correlate this interval to the *Hemiaulus peripterus* zone. These standard diatom zones correspond to the NP4-NP11 nannoplankton zones (Fig. 2). However, the presence in all associations of the silicoflagellate *Corbisema disymmetrica* Bukry, which is known only from the NP4-NP9 interval, allows us to suggest that the Sengiley diatomites are within the Palaeocene.

Thus, in all three (radiolarian, diatom, and silicoflagellate) assemblages, there are a number of stratigraphic markers which can be successfully used for the stratigraphic subdivision of early Palaeogene sediments and for the refinement of Palaeocene diatom zonation. These are the diatom species *Aulacodiscus suspectus* A. Schmidt, *Hemiaulus proteus* Heiberg, *Craspedodiscus moelleri* A. Schmidt, *Cylindrospira simsi* Mitlehner; and the radiolarian species *Tripodiscinus sengilensis* Kozlova, *T. trilobatus* Kozlova, *T. sibiricus* Kozlova, *Petalospyris foveolata* Ehrenberg, *P. fiscella* Kozlova, etc. Until now, these radiolarian species have not been found in open ocean sediments.

Palaeogeographic issues

During the middle-late Palaeocene, the Middle Volga Region was a shallow-water, highly productive marine basin with siliceous sedimentation. It is obvious that Palaeocene sediments of the Middle Volga Region are accumulated in the great gulf of the epicontinental sea, via an intensive upwelling process. Distanov (1968) supposed that diatomites may be accumulated in marginal parts of palaeodeltas. It is possible also that diatomite accumulation took place only on topographic highs of subbottom relief.

The main peculiarity of the siliceous microplankton assemblages is their provincialism. The taxonomic composition of the associations differs strongly from coeval oceanic assemblages. Deep-sea diatom Palaeocene assemblages, restricted generally to the Southern Hemisphere (Fenner 1991; Fourtanier 1991) differ taxonomically from epicontinental assemblages due to palaeoecological and palaeogeographical differences, and preservation factors. Epicontinental diatom assemblages of the Northern Hemisphere are highly diverse due to high percentages of meroplanktonic species.

Although Palaeocene diatom assemblages from the Southern Hemisphere and Volga Region differ strongly, the presence of common species suggests a connection between these areas of the World Ocean, possibly through the Tethys and East Atlantic. The geography of the connection between Middle Volga Region and West Siberian basins (including the eastern Urals slope), and the North European basins (Fur Formation, Denmark and Sambian Formation, Kaliningrad Region, Russia) with biosilica sedimentation (Strelnikova *et al.* 1978; Fenner 1994; Mitlehner 1996) is not still clear.

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APPENDIX

DIATOMS

Actinoptychus sp.
Aulacodiscus distinguendus Hustedt (1958) – Homann 1991, pl. 7, fig. 4.
Aulacodiscus probabilis A. Schmidt – Homann 1991, pl. 4, figs 3-5 (Fig. 7K).
Aulacodiscus schmidtii Wirt (1886) – *Aulacodiscus septus* A. Schmidt f. *septus* A. Schmidt Strelnikova 1974, pl. 19, figs 1-6, tab. 20, figs 1-5. (Fig. 7F).
Aulacodiscus suspectus A. Schmidt (1876) – Homann 1991: 37, pl. 6, figs 1-5; pl. 7, figs 1-3, 5 [= *Coscinodicus josefinus* Grunow – Strelnikova *et al.* 1978, pl. 15, figs 1, 2] [= *Coscinodiscus uralensis* Jousé – Proshkina-Lavrenko 1949: 73, pl. 24, fig. 4 (Fig. 6K)].

Briggera sibirica (Grunow) Ross & Sims, 1985: 300, pl. 3, figs 1-7. – Homann 1991: 74, pl. 8, Figs 1-11 [= *Biddulphia tuomeyi* (Bailey) Roper var. *tridenta* Jousé – Strelnikova *et al.* 1978, pl. 17, fig. 5 (Fig. 5D)].

Coscinodiscus anissimovae Gleser & Rubina, 1968: 153, pl. 1, figs 1-6. – Proshkina-Lavrenko 1974, pl. 38, fig. 8.
Coscinodiscus sp. Common occurrence of large *Coscinodiscus* is recorded at the Sengiley section. These belong mostly to *Coscinodiscus oculus iridis* Ehrenberg (1839) group, *Coscinodiscus radiatus* Ehrenberg (1839) group, and *Coscinodiscus argus* Ehrenberg (1838).
Costopyxis antiqua (Jousé) Gleser, 1984: 291 [= *Stephanopyxis antiqua* Jousé, 1951: 46, pl. 1, fig. 3. – Strelnikova 1974, pl. 3, figs 18-20].
Craspedodiscus moelleri A. Schmidt (1893) – Proshkina-Lavrenko 1974, pl. 23, fig. 2. – Homann 1991: 47, pl. 17, figs 1-5 (Fig. 6D).
Cylindrospira simsi Mitlehner, 1995: 323, figs 3-6, 9-18 [= *Pyxilla multiseptata* Gleser, 1995, pl. 1, fig. 16 (Fig. 6B)].

Eunotogramma variabile Grunow (1883) – Proshkina-Lavrenko 1974, pl. 15, fig. 12 (Fig. 5E).

Eunotogramma weissii Ehrenberg (1955) – Proshkina-Lavrenko 1974, pl. 5, fig. 6 (Fig. 4A).

Fenestrella antiqua (Grunow) Swatman (1948) – Homann 1991, pl. 18, figs 1, 2, 4, 5.

Grunowiella gemmata (Grunow) Van Heurck (1896) – Fenner 1991, pl. 11, fig. 13 (Fig. 6H).
Grunowiella palaeocaenica Jousé, 1951: 40-41, pl. 4, fig. 5. – Fenner 1991, pl. 11, figs 1-4 (Fig. 6I).

Hemialus ambiguus Grunow (1884) – Fenner 1994, pl. 6, fig. 17 (Fig. 5B, I).
Hemiaulus arcticus var. bornholmensis Cleve-Euler (1951) – Fenner 1994, pl. 8, Figs 1, 2 (Fig. 5F).
Hemiaulus curvatulus Strelnikova, 1971: 49, pl. 1, figs 12, 13. – Harwood 1988, figs 12, 13 (Fig. 5O, S).
Hemiaulus danicus Grunow (1878) – Homann 1991, pl. 20, figs 1-10 (Fig. 5N).
Hemiaulus frigidus (Grunow) Fenner, 1994: 112, pl. 8, fig. 4 (Fig. 5C).
Hemiaulus incisus Hajos, 1976: 829, pl. 23, figs 4-9. – Fenner 1991, pl. 10, fig. 9 (Fig. 5G).
Hemiaulus incurvus Shibkova *in* Krotov & Shibkova, 1959: 124, pl. 4, fig. 8. – Gombos 1977, pl. 16, figs 1-7 (Fig. 5A).
Hemiaulus proteus Heiberg, 1863 – Proshkina-Lavrenko 1974, pl. 19, fig. 3. – Homann 1991, pl. 24, figs 15-18 (Fig. 5P, R).
Hemiaulus cf. rossicus Pantocsek, 1889 – Proshkina-Lavrenko 1974, pl. 15, fig. 10 (Fig. 5L, M).
Hyalodiscus radiatus (O' Meara) Grunow var. ***arctica*** Grunow (1884) – Homann 1991, pl. 26, figs 3, 6-9.

Kentrodiscus fossilis Pantocsek (1889) – Harwood 1988, figs 16-18 [= *Pterotheca* sp. – Homann 1991, pl. 54, figs 7-9 (Fig. 7G)].

Lisitzinia distanovii Gleser, 1995, pl. 1, fig. 5 (Fig. 4C).

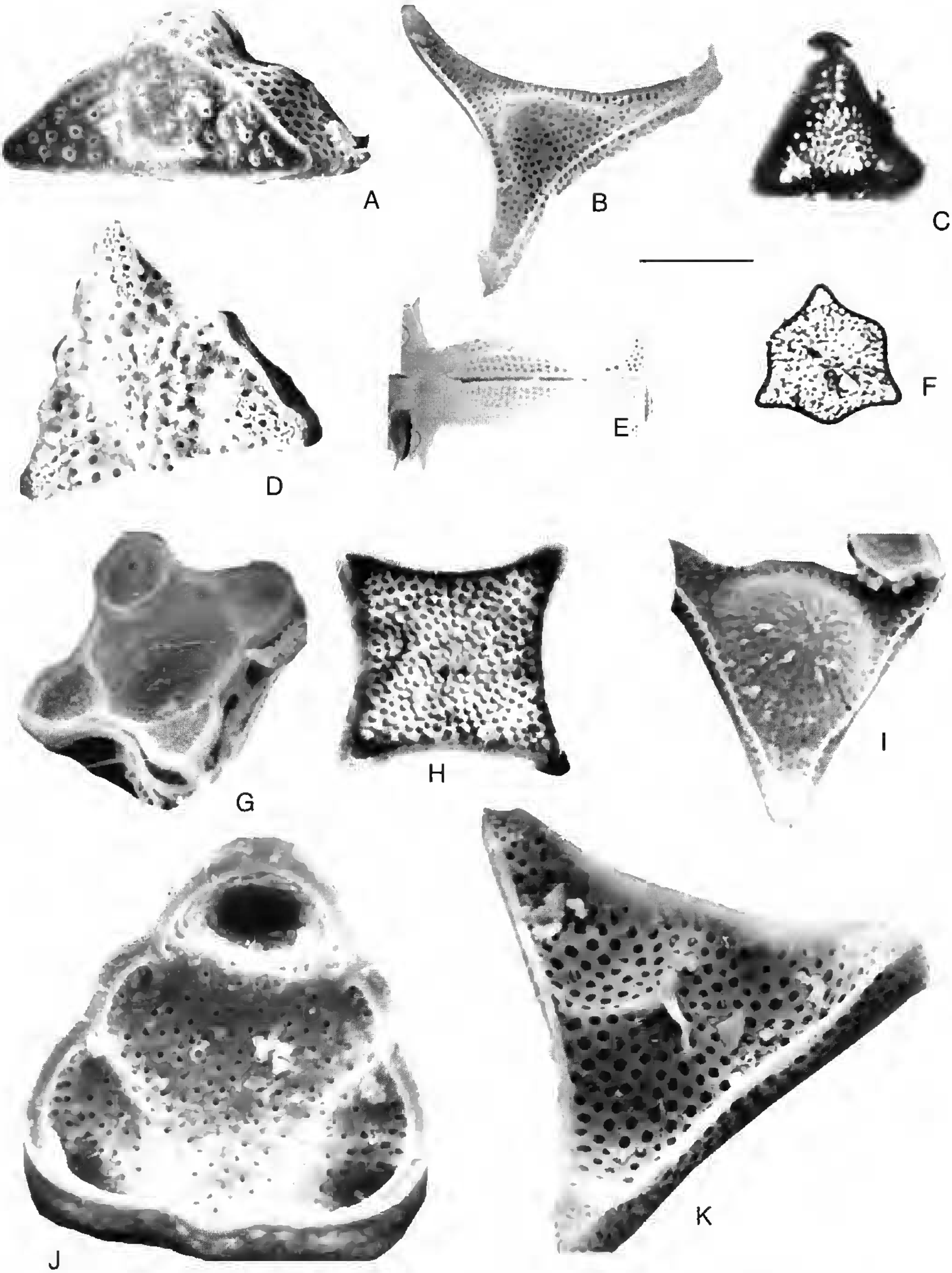

FIG. 4. — **A**, *Eunotogramma weissii* Ehrenberg, sample 100; **B**, **E**, *Trinacria excavata* Heiberg; **B**, sample 68; **E**, sample 58; **C**, *Lisitzinia distanovii* Gleser, sample 69; **D**, *Triceratium mirabile* Jousé, sample 100; **F**, *Triceratium sparsipunctata* Jousé, sample 67; **G**, *Solium exsculptum* Heiberg, sample 58; **H**, *Trinacria regina* Heiberg, sample 61; **I**, *Triceratium ventriculosum* A. S., sample 100; **J**, *Triceratium flos* Ehrenberg, sample 100; **K**, *Triceratium heibergii* Grunow, sample 58. Scale bar: A, B, D, G, I, J, 26.6 µm; C, 13.3 µm; E, 28.5 µm; F, 40 µm; H, 20 µm; K, 23.5 µm.

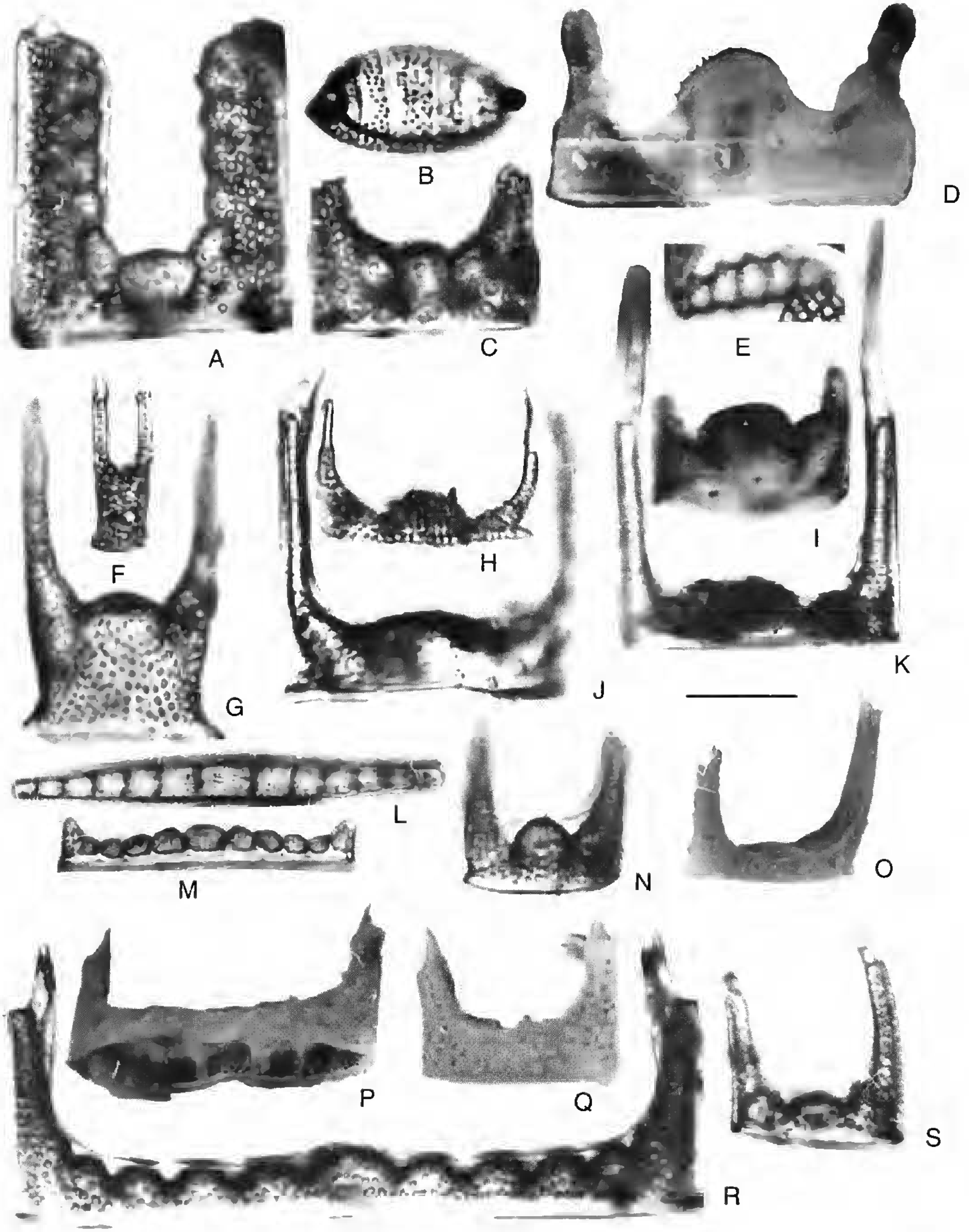

FIG. 5. — **A**, *Hemiaulus incurvus* Shibkova, sample 85; **B**, **I**, *Hemiaulus ambiguus* Grunow, sample 85; **C**, *Hemiaulus frigidus* (Grunow) Fenner, sample 67; **D**, *Briggera sibirica* (Grunow) Ross & Sims, sample 58; **E**, *Eunotogramma variabile* Grunow, sample 88; **F**, *Hemiaulus arcticus* var. *bornholmensis* Cleve-Euler, sample 103; **G**, *Hemiaulus incisus* Hajos, sample 58; **H**, **J**, **K**, *Hemiaulus* sp.; **H**, sample 103; **J**, sample 109; **K**, sample 109; **L**, **M**, *Hemiaulus* cf. *rossicus* Pantocsek, sample 67; **N**, *Hemiaulus danicus* Grunow, sample 88; **O**, **S**, *Hemiaulus curvatulus* Strelnikova; **O**, sample 58; **S**, sample 67; **P**, **R**, *Hemiaulus proteus* Heiberg; **P**, sample 58; **R**, sample 61; **Q**, *Hemiaulus* sp., sample 75. Scale bar: A-C, E-N, R, S, 20 µm; D, O-Q, 26.6 µm.

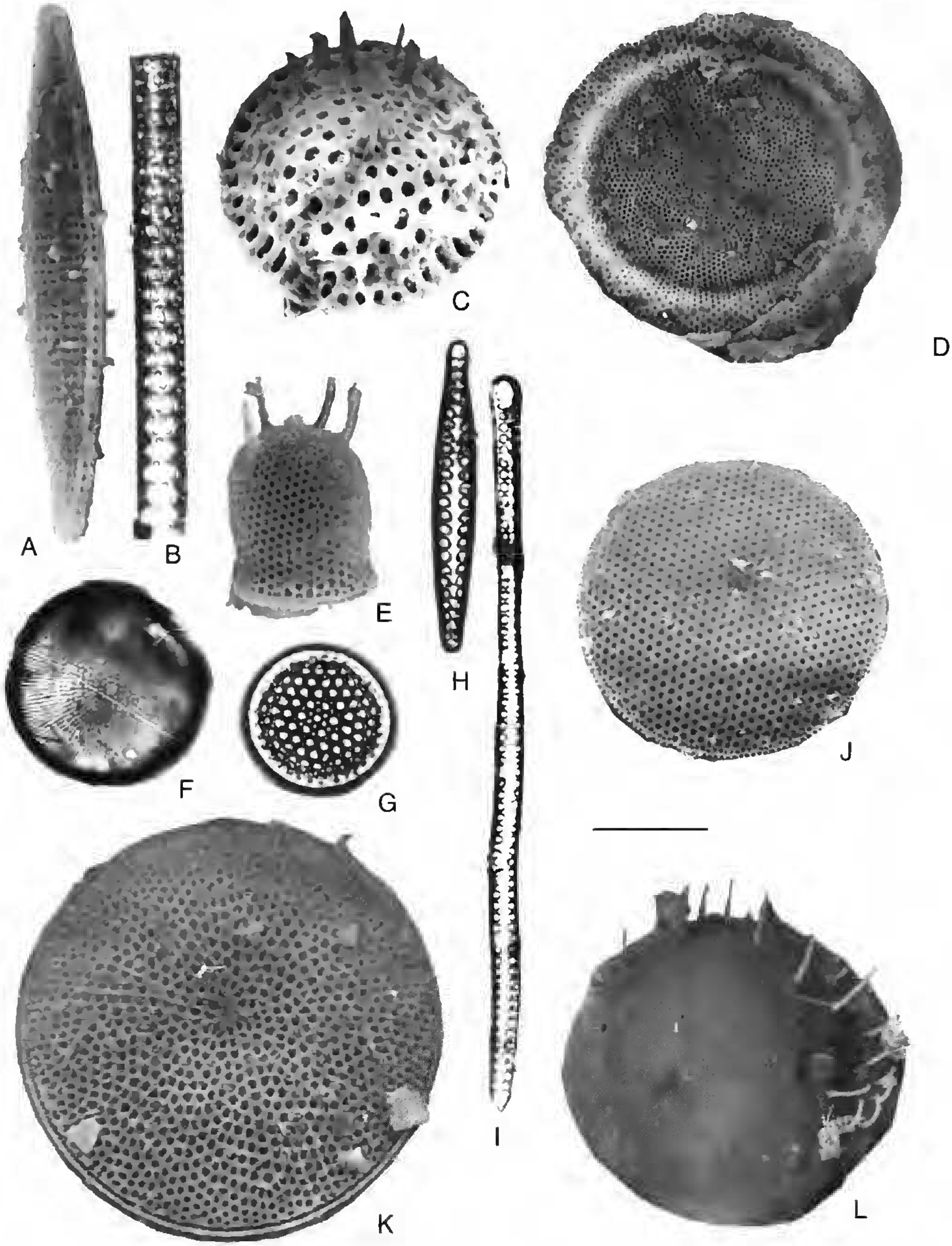

FIG. 6. — **A**, *Rhaphoneis simbirskiana* Grunow & Pantocsek, sample 58; **B**, *Cylindrospira simsi* Mitlehner, sample 67; **C**, *Pyxidicula ferox* (Greville) Strelnikova & Nikolaev, sample 100; **D**, *Craspedodiscus moelleri* A. Schmidt, sample 58; **E**, *Pyxidicula turris* (Greville & Arnott) Strelnikova & Nikolaev, sample 100; **F**, *Thalassiosira* sp. 1 *sensu* Fourtanier, sample 59; **G**, *Pyxidicula* sp., sample 74; **H**, *Grunowiella gemmata* (Grunow) Van Heurk, sample 100; **I**, *Grunowiella palaeocaenica* Jousé, sample 58; **J**, *Thalassiosiropsis wittiana* (Pantocsek) Hasle, sample 100; **K**, *Aulacodiscus suspectus* A. Schmidt, sample 58; **L**, *Pyxidicula* sp., sample 58. Scale bar: A, H, K, 16.6 µm; B, F, G, I, 20 µm; C, 13.3 µm; D, J, 26.6 µm; E, 28.5 µm; L, 25 µm.

Odontotropis carinata Grunow (1884) – Homann 1991, pl. 27, figs 5, 7; pl. 28, figs 1-3 [= *Odontotropis danicus* Debes – Fenner 1985: 734, pl. 14, fig. 11 (Fig. 7I, J).
Odontotropis cristata Grunow (1884) – Homann 1991, pl. 29, figs 1-5.

Paralia crenulata (Grunow) Gleser *stat. nov.* – Makarova 1992: 50, pl. 41, figs 1-8.
Paralia grunowii Gleser *stat. et nom. nov.* – Makarova 1992: 51, pl. 41, figs 9-11; pl. 42.
Paralia sulcata (Ehrenberg) Cleve (1884) – Makarova 1992: 52, pl. 43.
Proboscia cretacea (Hajos & Stradner) Jordan & Priddle, 1991: 56 [= *Rhizosolenia cretacea* Hajos & Stradner, 1975: 929, pl. 7, fig. 1; pl. 31, figs 4-6. – Fenner 1991, pl. 1, figs 4-9].
Pseudopodosira westii (W. Smith) Sheshukova & Gleser, 1964, pl. 1, figs 4, 5.
Pseudopodosira sp. 2 *sensu* Homann, 1991: 134, pl. 54, figs 9, 10.
Pseudostictodiscus angulatus Grunow (1876) – Fenner 1994, pl. 3, figs 12-17 (Fig. 7D).
Pterotheca major Jousé, 1955: 101, pl. 6, fig. 2. – Harwood 1988, figs 16, 18.
Pyxidicula ferox (Greville) Strelnikova & Nikolaev – Makarova 1988: 41, pl. 23, figs 7, 8 (Fig. 6C).
Pyxidicula moelleri (A. Schmidt) Strelnikova & Nikolaev, 1986: 952 [=*Coscinodiscus moelleri* A. Schmidt – Homann 1991, pl. 10, figs 4-8 (Fig. 7A).
Pyxiducula sp. Common occurrence of different *Pyxidicula* is observed in the upper part of Granoe Ukho section. Most of these belongs to *Pyxidicula turris* (Greville & Arnott) Strelnikova & Nikolaev, 1986 group and *Pyxidicula corona* (Ehrenberg) Strelnikova & Nikolaev, 1986 group.

Rattrayella oamaruensis (Grunow) De Toni (1896) – Homann 1991, pl. 33, figs 1-7 (Fig. 7C).
Rattrayella rotundata (Shibkova) Gleser, 1995, pl. 1, fig. 20. (Fig. 7B).
Rhaphoneis morsiana Grunow *in* Pantocsek (1886-89) *em.* Homann 1991: 129, pl. 34, figs 9-12.
Rhaphoneis simbirskiana Grunow *in* Pantocsek (1886-89) – Proshkina-Lavrenko 1974, pl. 15, fig. 15 (Fig. 6A).
Rhizosolenia hebetata Bailey (1856) – Homann 1991, pl. 36, figs 5, 11, 12.
Solium exsculptum Heiberg (1863) – Homann 1991, tf. 37, figs 1, 3, 5-7 [= *Trinacria exsculpta* (Heiberg) Hust. – Mukhina 1976, pl. 2, fig. 7 (Fig. 4G).
Stellarima microtrias (Ehrenberg) Hasle & Sims, 1986: 11, figs 18-27.

Thalassiosira sp. 1 *sensu Thalassiosira* ? sp. 1 *sensu* Fourranier, 1991, pl. 1, fig. 12 [= Genus and specie indet. – Schrader & Fenner 1976, pl. 33, fig. 7 (Fig. 6F)].
Thalassiosiropsis wittiana (Pantocsek) Hasle, Hasle & Syversten, 1985, 89 f, Abb. 1-41. – Homann 1991, pl. 37, figs 8-10 (Fig. 6J).
Triceratium flos Ehrenberg (1885) – Homann 1991, pl. 44, figs 1, 2, 6 (Fig. 4J).
Triceratium heibergii sensu Gombos, 1977, pl. 1, figs 1-12 [= *Triceratium caudatum* Witt, Proshkina-Lavrenko, 1974, pl. 15, fig.] [= *Trinacria muricata* Gleser, 1995, pl. 1, fig. 4 (Fig. 4K)].
Triceratium kinkeri A. Schmidt (1874-1959) – Prosh-kina-Lavrenko 1974, pl. 23, fig. 3.
Triceratium mirabile Jousé *in* Proshkina-Lavrenko, 1949: 166, pl. 6, fig. 5 – Fenner 1991, pl. 9, figs 7-10 (Fig. 4D).
Triceratium sparsipunctata Jousé, *in* Proshkina-Lavrenko 1949: 169, pl. 64, fig. 6 (Fig. 4F).
Trinacria ventriculosa (A. Schmidt) Gleser, *in* Proshkina-Lavrenko 1974, pl. 18, fig. 12 (Fig. 4I).
Trinacria excavata Heiberg (1863) – Homann 1991, pl. 46, figs 1-8; pl. 47, figs 1-6. (Fig. 4B, E).
Trinacria pileolus (Ehrenberg) Grunow (1884) – Gombos 1977, pl. 37, figs 3, 4.
Trinacria regina Heiberg (1863) *em.* Homann 1991: 124, pl. 50, figs 1-7; pl. 51, figs 1-7. – Proshkina-Lavrenko 1974, pl. 23, fig. 6 (Fig. 4H).
Trochosira spinosa Kitton (1871) – Homann 1991, pl. 17, figs 6-13.

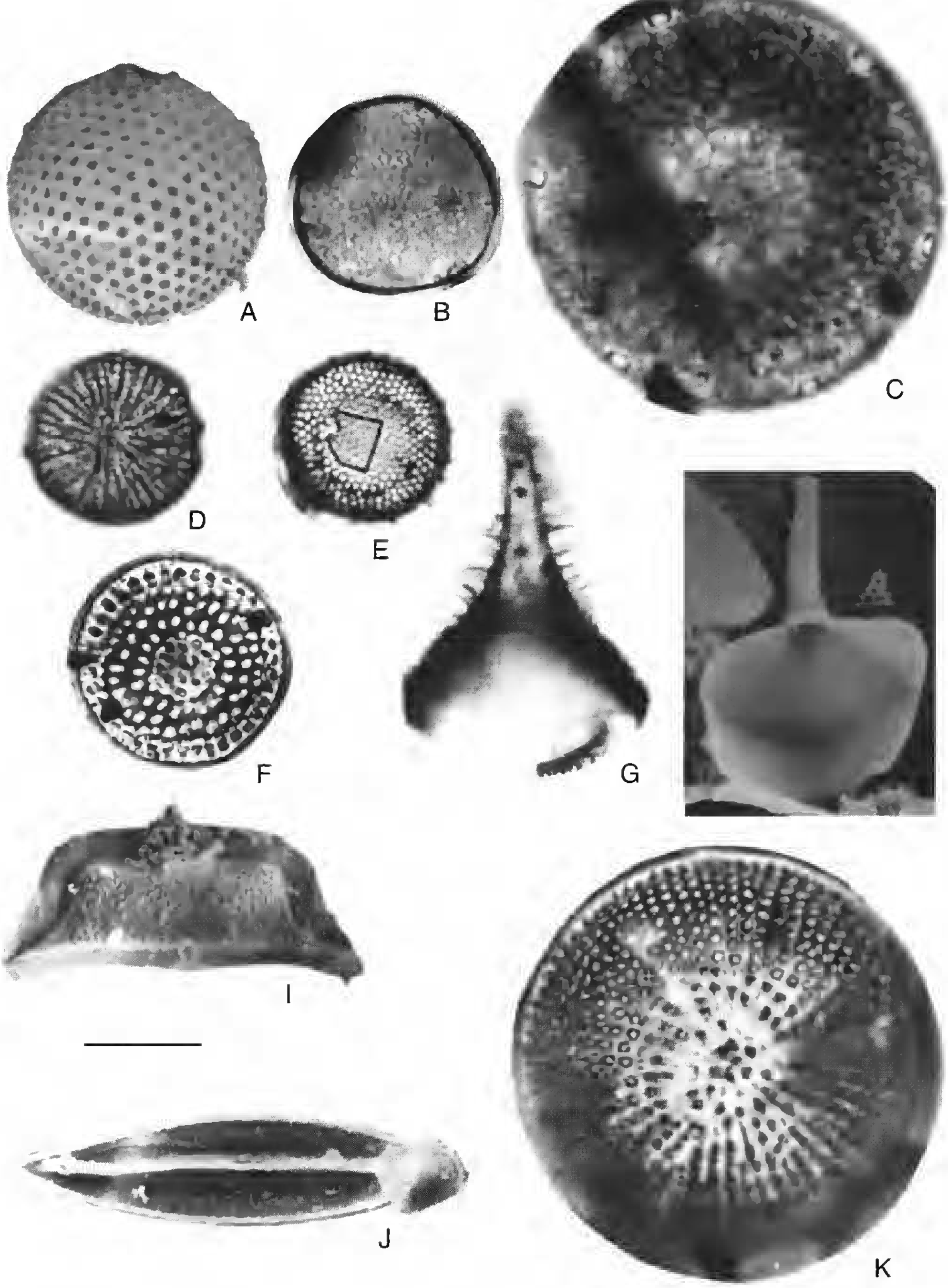

FIG. 7. — **A**, *Pyxidicula moelleri* (A. Schmidt) Strelnikova & Nikolaev, sample 58; **B**, *Rattrayella rotundata* (Shibkova) Gleser, sample 79; **C**, *Rattrayella oamaruensis* (Grunow) De Toni, sample 87; **D**, *Pseudostictodiscus angulatus* Grunow, sample 74; **E**, *Pyxidicula* sp., sample 58; **F**, *Aulacodiscus schmidtii* Witt, sample 74; **G**, *Kentrodiscus fossilis* Pantocsek, sample 94; **H**, *Pterotheca* sp., sample 100; **I**, **J**, *Odontotropis carinata* Grunow, sample 100; **K**, *Aulacodiscus probabilis* A. Schmidt, sample 88. Scale bar: A, 14.2 µm; B-D, G, K, 20 µm; E, 40 µm; F, 13.3 µm; H-J, 26.6 µm.

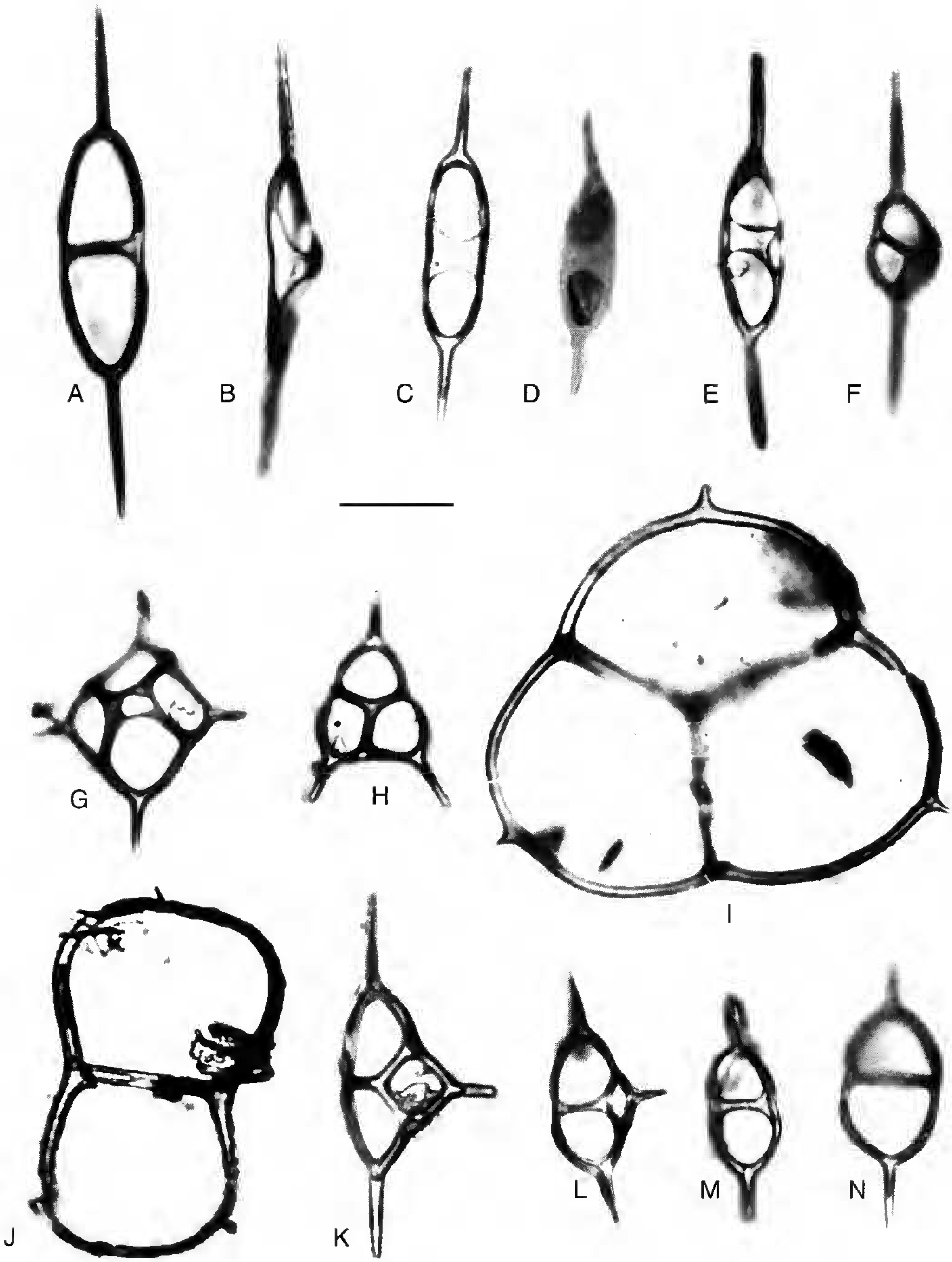

FIG. 8. — **A-D**, *Naviculopsis constricta* (Schulz) Frenguelli; **A**, sample 74; **B**, sample 58; **C**, sample 67; **D**, sample 58; **E**, *Naviculopsis punctilia* Perch-Nielsen, sample 67; **F**, *Naviculopsis danica* Perch-Nielsen, sample 67; **G**, *Dictyocha precarentis* Bukry, sample 88; **H**, *Corbisema hastata hastata* (Lemmermann) Bukry, sample 108; **I**, *Corbisema hastata globulata* Bukry, sample 58; **J**, *Corbisema disymmetrica* var. *communis* Bukry, sample 109; **K**, **L**, *Dictyocha elongata* Glezer; **K**, sample 88; **L**, sample 95; **M**, **N**, *Naviculopsis robusta* Deflandre; **M**, sample 74; **N**, sample 109. Scale bar: A-C, E-N, 20 µm; D, 26.6 µm.

Xanthiopyxis sp. 1-form 7 *sensu* Homann 1991, pl. 57, figs 14, 15.

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Corbisema disymmetrica var. *communis* Bukry, 1976: 891, pl. 1, figs 5-9. – Perch-Nielsen 1985, fig. 11(8) [= *Dictyocha navicula* Ehrenberg, Gleser 1966: 251, pl. 9, figs 4, 5; text-fig. 6(6)] [= *Corbisema naviculoidea* (Frenguelli) Perch-Nielsen, 1976: 33, fig. 7, 19, 22 (Fig. 8J)].
Corbisema hastata hastata (Lemmermann) Bukry, 1976: 892, pl. 4, figs 9-16. – Perch-Nielsen 1985, fig. 11 (22, 23) (Fig. 8H).
Corbisema hastata globulata Bukry, 1976: 892, pl. 4, figs 7, 8 (Fig. 8I).
Corbisema inermis inermis (Lemmermann) Bukry, 1976: 892, pl. 5, figs 1-3.

Dictyocha elongata Gleser, 1960: 131, 132, tabl. 1, pl. 2, figs 16-20. – Perch-Nielsen 1976, fig. 2 (Fig. 8K, L).
Dictyocha fibula Ehrenberg (1839) – Perch-Nielsen 1985, fig. 15 (17).
Dictyocha precarentis Bukry, 1976: 894, pl. 6, figs 6-13; pl. 7, figs 1-3 (Fig. 8G).

Naviculopsis constricta (Schulz) Frenguelli, (1940) – Perch-Nielsen 1985, figs 26 (6, 7) (Fig. 8A-D).
Naviculopsis danica Perch-Nielsen, 1976: 35, figs 5, 6, 21. – Gleser 1995, pl. 1, fig. 27 (Fig. 8F).
Naviculopsis punctilia Perch-Nielsen, 1976: 36, figs 26, 27; 1985, fig. 26 (33) (Fig. 8E).
Naviculopsis robusta Deflandre (1950) – Gleser 1995, pl. 1, fig. 29 (Fig. 8M, N).

RADIOLARIA

Anthocyrtoma (?) frizzeli Nishimura, 1992: 332, pl. 9, fig. 13, 14; pl. 13, fig. 8.

Botryometra (?) osha Kozlova, 1978: 95, 96, pl. VI, fig. 9, 10; pl. XIX, fig. 3.

Buryella tetradica Foreman, 1973: 443, 8, figs 4, 5; pl. 9, figs 13, 14. – Kozlova 1984, pl. XII, fig. 16 [= *Lithocampium* sp. A – Riedel & Sanfilippo 1971, pl. 7, fig. 12].

Clathrocyclas elegans (Lipman, 1958) – Kozlova 1978, pl. 17, figs 1, 4, 5. – Kozlova 1990: 78, pl. XII, fig. 14. – Petrushevskaya & Kozlova 1979, fig. 500 [= *Theocorys sporta* Kozlova *in* Kozlova, Gorbovetz 1966: 11, pl. 17, fig. 8.
Clathrocyclas extensa Clark & Campbell, 1942: 85, pl. 8, fig. 11. – Bjorklund 1977, pl. 21, fig. 4. – Kozlova & Gorbovetz 1966, pl. 21, fig. 8. – Petrushevskaya & Kozlova 1979: 131, fig. 38b, 504.
Clathrocyclas lipmanae Kozlova, 1978: 121, pl. 6, fig. 3, 6. pl. 17, fig. 12, pl. 19, fig. 8. – Kozlova 1990: 78, pl. XII, fig. 21.
Clathrocyclas longispina Clark & Campbell, 1942 – Kozlova 1978, pl. XVII.

Diplocyclas cornuta runjevae Kozlova, 1978: 124, pl. VI, fig. 1 ,4, pl. XIX, fig. 6.
Diplocyclas pseudobicorona pseudobicorona Nishimura, 1992: 340, pl. 4, figs 4-6, pl. 13, fig. 14.

Larnacalpis (?) smili Middour-Kozlova 1978, pl. IX, figs 3, 5.
Lophophaena curta Kozlova, 1978, pl. V, figs 7, 8; pl. XIX, fig. 4.

Peritiviator (?) dumitricae Nishimura, 1992: 328, pl. 1, fig. 13-16, pl. 11, figs 11, 12.
Petalospyris fiscella (Kozlova) – *Tetraspyris fiscella* Kozlova *in* Kozlova & Gorbovetz 1966: 92, tabl. XV, fig. 1 [= *Hexaspyris* sp. – Petrushevskaya & Kozlova 1972, pl. 40, fig. 6] [= *Hexaspyris fiscella* (Kozlova) – Kozlova 1978: 89, pl. VIII, fig. 6].
Petalospyris foveolata Ehrenberg & Kozlova, 1978: 89-90, pl. 6, fig. 8; pl. 8, fig. 10; pl. 19, figs 9-13.
Petalospyris tumidula Kozlova *in* Kozlova & Gorbovetz, 1966: 97, pl. XV, figs 10, 11.
Phormocyrtis reticula (Kozlova) [= *Theocorys reticula* Kozlova *in* Kozlova & Gorbovetz, 1966: 110, pl. XVII, fig. 7].
Plectodiscus totchilinae Kozlova, 1984: 206-207, pl. X, fig. 13.

Spongasteriscus cruciferus Clark & Campbell, 1942 – Kozlova 1984, pl. X, fig. 16.
Spongodiscus americanus Kozlova *in* Kozlova & Gorbovetz, 1966, tabl. XIV, figs 1, 2. – Sanfilippo & Riedel 1973: 524, pl. 27, fig. 11; pl. 28, fig. 9 [= *Spongodiscus americanus americanus* Kozlova, 1978: 77, tabl. XIV, fig. 3].
Spongomelissa numa callosa Kozlova, 1978: 101, pl. XII, fig. 2; pl. XIX, fig. 2.
Spongomelissa numa numa Kozlova, 1978: 100, 101, pl. XII, figs 4, 5.
Spongomelissa (?) ternaria Kozlova, 1978: 101, 102, pl. VIII, fig. 1; pl. XIX, fig. 1.
Spongotrochus alveatus Riedel & Sanfilippo *in* Sanfilippo & Riedel, 1973: 525, pl. 13, figs 4, 5; pl. 30, figs 3, 4. – Kozlova 1984, pl. XI, fig. 6.
Spongotrochus helioides (Cleve) – [= *Spongotrochus* sp. *aff. Trochodiscus helioides* Cleve – Kozlova 1978: 82, 83, pl. 16, fig. 6].
Spongotrochus nativus praecox Kozlova, 1978: 78, pl. 14, fig. 1.
Spongotrochus paciferus antiquus Kozlova, 1978, tabl. XVI, figs 4, 5.
Spongotrochus puter Kozlova, 1978: 82, pl. 5, fig. 10.

Thecosphaerella rotunda Borissenko, 1960: 222, pl. 1, fig. 3, pl. 3, figs 2, 3. – Sanfilippo & Riedel 1973: 522, pl. 26, fig. 3 [= *Thecosphaera melitomma* Kozlova *in* Kozlova & Gorbovetz 1966: 52, pl. VII, figs 7, 8].
Tripodiscinus sengilensis Kozlova, 1978: 104, 105, pl. V, figs 1-5; 1984: 207, 208, pl. XII, 20.
Tripodiscinus sibiricus Kozlova, 1978: 103, 104, pl. XII, fig. 3; 1984: 208, pl. XII, fig. 4 [= ***Tripodiscinus tumulosa*** (Kozlova) – Petrushevskaya 1971, figs 33-V-VI] [= *Tripodiscinum* sp. A – Petrushevskaya 1971, figs XI-XII].
Tripodiscinus trilobatus Kozlova, 1978, pl. X, figs 4, 5.